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RESEARCH ARTICLE

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ENHANCEMENT OF VOLTAGE STABILITY USING FACTS DEVICES

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ABSTRACT

Maintaining voltage stability is important for secure operation of power system. It is necessary to keep bus voltages within permissible limits. Bus voltages and angles are monitored by performing load flow analysis. Stability level of buses is calculated to find weak buses in the system and to predict where instability may occur so that proper measures can be taken. FACTS devices are used to achieve objectives such as improving stability, reducing losses, increasing loadability etc. By placing FACTS devices at proper location voltage stability can be enhanced. In this paper voltage stability index using L-index method is used to find location of FACTS device.

Keywords: FACTS, Load flow, L-index, SVC, Voltage stability.

I. INTRODUCTION

For many years, voltage collapse problems in power systems has been a concern for electric utilities and a subject of great importance due to the events of voltage instability and collapses that have occurred worldwide [1]. Voltage collapse is due to voltage instability. Voltage instability is the inability of a power system to maintain steady state voltages at all buses following a disturbance. However, voltage collapse is defined as the process by which the sequence of events accompanying voltage instability leads to a blackout or abnormally low voltages in a significant part of the power system [2]. Voltage collapse typically occurs on power systems that are heavily loaded, faulted and/or have reactive power shortage. Voltage varies slowly until maximum loading point. At this point voltage decreases rapidly resulting in voltage collapse. The voltage collapse problem is closely related to a reactive-power planning problem including contingency analyses, where suitable conditions of reactive-power reserves are necessary for secure operations of power systems. The loadability margin of a system is defined as the amount of power that the system can supply before it undergoes voltage collapse.

Flexible AC Transmission System (FACTS) devices can be very helpful in the operation of power networks. They are solid state converters that have the capability to control various electrical parameters in transmission networks. They can provide direct and flexible control of power transfer. Both the power system performance and the power system stability can be enhanced by utilizing FACTS devices [3]. Conventionally the optimal operation of the power system networks has been based on economic criterion. Now other criterion such as improving voltage profile and minimizing power loss of transmission line are taken into consideration. The

Flexible AC Transmission System (FACTS) have been considered to maximize the use of existing transmission facilities. They can enhance voltage stability by providing reactive power support at buses. They can reduce flow in heavily loaded line which results in increased loadability, improved security and stability of the power system.

II. FACTS DEVICES

The proper utilization of FACTS devices gives the following benefits [4].

1) Reduced transmission losses

2) Improved voltage stability

3) Improved controllability and system security

4) Enhanced power transfer capacity of the transmission network

In this paper Static Var Compensator (SVC) is used to enhance voltage stability. SVC is a shunt connected device and is designed for maintaining bus voltages within permissible limits in power systems. It helps in increasing the loading margin of the system. Thus, they are increasingly used in stressed transmission systems.

A. Static VAR Compensator (SVC): SVC is shunt connected type FACTS device whose output is adjusted to control various parameters of the power system such as reactive power, bus voltage etc. The SVC consists of thyristor controlled or switched reactor (TSR) and/or thyristor switched capacitor (TSC) or a combination as shown in Fig. 1. TSR is used for absorbing reactive power and TSC is used to supply the reactive power under abnormal conditions of network.

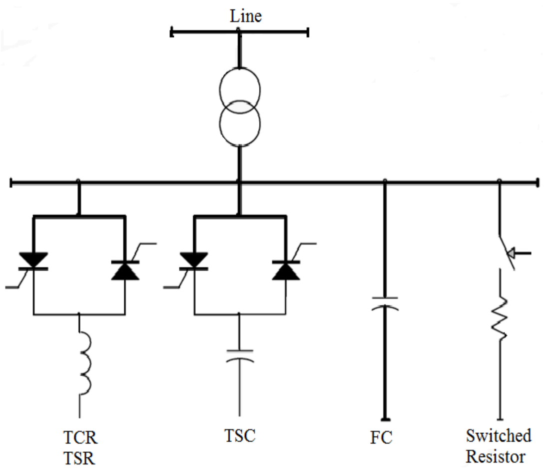

Fig. 1 Schematic diagram of SVC

III. VOLTAGE STABILITY INDEX

In power system, the stability level of all buses and the weakest bus among them are identified with the help of the stability indices. Lee's stability margin, Schlueter's stability indicator, and Kassel's bus stability index, Voltage Stability Index (VSI) and Line Stability Index (LSI) are the various types of stability indices used in power system to monitor the system stability. In this paper voltage stability index using L-index method is used to find the stability levels of all load buses.

L-index method is used to calculate the stability indices for all the load buses connected in an IEEE 14 bus network [5]. By using the load flow results obtained from Newton Raphson Technique, the Voltage Stability index (L-index) for load buses is to be computed as

$$L_j = \left| 1 - \sum_{i=1}^{g} F_{ji} \frac{V_i}{V_j} \right| \quad (1)$$

The values of F_{ji} can be obtained from Y bus matrix

$$F_{ji} = [Y_{LL}]^{-1} [Y_{LG}] \quad (2)$$

Where Y_{LL} and Y_{LG} are corresponding partitioned portions of the Y-bus matrix [6]. The L-indices for a given load condition are computed for all load buses. The L index gives a scalar number to each load bus. If the index value (L index) is moving towards zero, then the system is considered as stable and also improves system security. When this index value moves away from zero, the stability of system relatively decreases and the system is considered as unstable. The L indices are calculated for all the load buses and the maximum of the L indices gives the proximity of the system to voltage collapse. The bus having highest value of L-index is the suitable location for placing FACTS device.

IV. CASE STUDY

IEEE 14 bus system is used in this paper. The IEEE 14 bus system includes 5 generator buses, 9 load buses and 20 transmission lines. The single line diagram of IEEE 14 bus test system is shown in Fig 2. Newton Raphson load flow analysis is done for base case which gives bus voltages and line losses. The result obtained through load flow analysis is used to calculate voltage stability index (L-index) for each load bus and it is shown in Table 1.

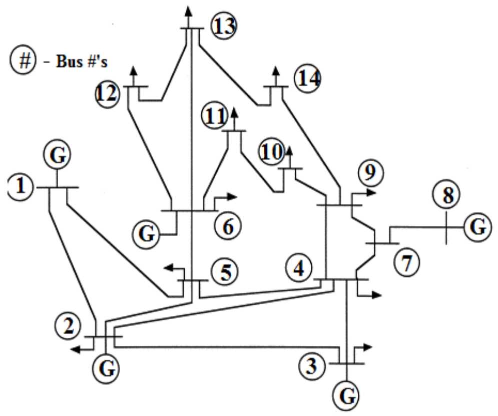

Fig. 2 IEEE-14 Bus System

TABLE 1 VSI for each load bus

Load Bus	L-index
4	0. 0122
5	0. 0138
7	0. 0189
9	0. 0244
10	0. 0224
11	0. 0143
12	0. 0106
13	0. 0115
14	0. 0220

The maximum value of L-index is at bus 9, therefore SVC is connected at this bus.

A. Comparison of bus voltages before and after connecting SVC

After finding suitable location of SVC, it is connected at that location and load flow is performed again to get new results. These results are compared with previous results. This comparison is shown in Table 2. From Table 2 it is clear that after connecting SVC bus voltages are improved. Graphical representation of comparison of bus voltages is shown in Fig. 3.

TABLE 2 Comparison of bus voltages

	Voltage(p.u)	
Bus No.	**Before SVC**	**After SVC**
1	1.06	1.06
2	1.035	1.035
3	1	1
4	0.9873	0.9944
5	0.9924	0.9971
6	1.01	1.01
7	0.9868	1.0126
8	0.99	1.01
9	0.9742	1.0135
10	0.9725	1.0051
11	0.9872	1.0039
12	0.9926	0.9956
13	0.9859	0.9917
14	0.9599	0.9851

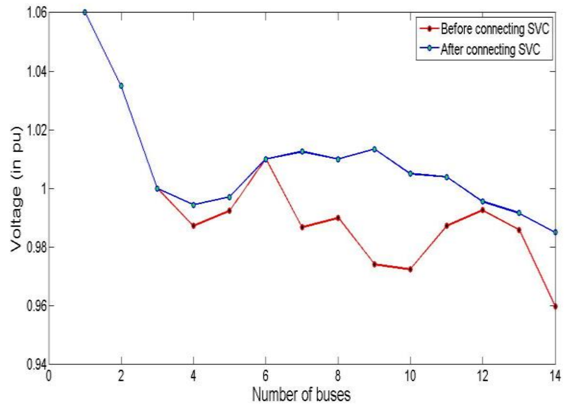

Fig. 3 Voltage profile

B. Comparison of losses

In addition to improving bus voltages FACTS devices also help in reducing line losses. Table 3 compares active power losses in the lines before and after connecting SVC

TABLE 3 Comparison of line losses

Line No.	Active power loss(MW)	
	Before SVC	**After SVC**
1	4.339	4.320
2	2.878	2.840
3	2.446	2.429
4	1.790	1.763
5	1.021	0.974
6	0.521	0.446
7	0.489	0.540
8	0.000	0.000
9	0.000	0.000
10	0.000	0.000
11	0.115	0.040
12	0.089	0.076
13	0.277	0.218
14	0.000	0.000
15	0.000	0.000
16	0.007	0.030
17	0.109	0.172

18	0.044	0.010
19	0.011	0.005
20	0.101	0.043
Total	14.237	13.906

Fig. 4 shows comparison of losses in graphical form.

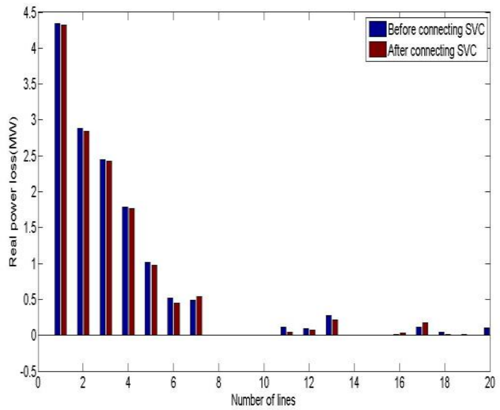

Fig. 4 Comparison of active power losses

From Table 3 it is clear that active power losses in the lines are reduced by connecting SVC at suitable location.

V. CONCLUSION

Voltage stability is one of the most important factors for safe and secure operation of power system. In this paper SVC has been successfully placed to maintain real power losses and voltage deviations. The location of SVC is found based on L-index. Simulations performed on IEEE 14 bus indicate that by placing SVC at suitable location not only voltage profile is improved but line losses are also reduced.

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